RHODA: A proposed Rapid Hand-Operated Digitizing Apparatus for the measurement of track chamber photographs

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1. Introduction

This apparatus has been inspired by the "shaky table" of Luis Alvarez and has these points in common with it: it uses a projector to throw a picture of the film down onto a horizontal table, a lattice of accurate "bench marks" to measure against, and it does not ask the operator to make accurate settings. It is simple and cheap and needs no computer on line; it should be accurate as the bench marks and quite fast though it requires a little more skill and thought in use.

2. General description (Figure 1)

The part handled by the operator is a flat round box, white on top, about 10 cm in diameter. It is slid along the projection table until the track wanted falls on it, and then adjusted until the track lies between the two red lines R and is about parallel to them, with the point whose coordinates are wanted on the centre line. That setting can be done quite fast as it need not be accurate. The operator then presses a pedal; this causes the sliding piece S to travel about 1 cm (as shown by the arrow) in about half a second and then quickly back again. A photocell under the scanning slit A records the dip in brightness as A crosses the track image; the distance the slit A has to travel to the middle of the track is digitized (see later).

In addition we need the accurate location of the box, and the angle α between the x-axis and the direction in which the sliding piece moved. A simple coded disc can give us α to $\pm$ 0.7° (8 bits) which is good enough. The <u>approximate</u> position of the box is obtained by two further coded discs which measure the angles between the arms of a simple elbow linkage by which the box is connected to the table. Such a system has been built by Adair and is known to give quite good accuracy, certainly the $\pm \frac{1}{2}$ mm which we need here.

The accurate position of the box is obtained by reference to a lattice of precisely positioned bench marks. A raster of clear "polka dots" (about 0.1 mm in diameter, with a lattice constant of about 0.5 mm) on a coloured, say yellow, background is clamped against the track film and projected together with it. The photocell behind the slit A is protected by a yellow filter so that the dots don't affect it; but there are two more slits B and C on the movable slide, and the photocells behind them are protected by a blue filter so that they receive no light unless the slit B (or C) moves over a dot. B and C are of such length and are staggered so that neither can pass two dots at once (which might cause ambiguous signals), yet one or the other is bound to cross a dot within the 1 cm travel of the sliding piece S which carries all the slits. The signal from the photocell behind B (or C) is used to digitize the distance S has to travel to the nearest dot; if both B and C produce signals the better signal is selected (see below).

3. Details

Let us assume 10-fold magnification for the projector, which should be enough for the crude settings required. The projected dots are then 1 mm in diameter, 5 mm apart. The tracks will look about 0.2 mm wide. Slit A should have about that same width, 0.2 mm. Its length might be 5 mm; with that length a misalignment by 2^o (easily avoided) or a radius of curvature of 15 mm (on the table) will not worsen the signal much.

The signal - light intensity through A, as a function of the distance A has travelled - will look somewhat like figure 2, and we require the distance a to the centre of the track, accurate to 0.02 mm (i.e., 2 μ on the film). It is easy to set to $\pm \frac{1}{2}$ mm, hence 6 bits of information are enough. To get that information I propose to square the signal (see fig. 2) and use it to gate a clock signal (c), generated by a magnetic pickup, from a tape attached to the sliding piece S. The clock signal will be transmitted at full frequency until the gate opens, then at half frequency until the gate closes again, and then no more; in that way the total number of pulses transmitted is a measure of the distance to the middle of the track. That number is converted into digital form (binary or decimal) by electronics outside the box and finally punched on tape.

Slits B and C are 3.5 mm long and staggered with an overlap (Fig. 3) of 1 mm; hence neither can touch two dots at once, but one of them must traverse a whole dot before long, giving a standard signal (3a). Sub--standard signals (when only the end of a slit passes over a dot, or when a dot is partly obscured by a track or a smudge) will be rejected by the electronics; if both slits produce standard signals the one from slit C will be rejected. If both signals are substandard the operator will receive an acoustic signal, telling him to try another point along the track; this should not happen often. The signals will be squared and digitized in much the same way as those from slit A. The gate that halves the rate of the clock signals must not operate before the photocell has been in darkness (the slit may have been on a dot when it started to move, and that dot must of course be disregarded), and both trains of pulses must be counted and the numbers stored, before one of them is rejected (or both) as being substandard. Probably a signal can be accepted if it has the correct number of half-rate pulses, corresponding to the full width of the dot, though one might think up other tests.

The longest travel needed will be about 3 mm (see Fig. 3), so about 9 bits of information are required; one further bit must be punched to tell the computer whether the signal came from slit B or C.

So each time the pedal is pressed the following data will be punched on the tape; the "elbow angles", indicating the approximate coordinates X and Y of the centre of the box, accurate to about $\pm \frac{1}{2}$ mm (say 10 bits each if an area of not quite a square metre is to be covered on the table); the angle α; the distance <u>a</u> by which S had to travel before the slit A passed the centre of the track; the distance <u>b</u> (or <u>c</u>) by which S had to travel before the slit B (or C) passed the centre of the nearest dot;

and one more digit which is 1 if b and 0 if c is punched. That makes 44 bits in all; on 5-hole tape, with each number recorded as a separate row of holes, each row with a parity check, we need 13 rows.

That, and the need for a special computation to obtain the accurate coordinates, is the price we pay for getting accurate figures by a stepwise, roundabout procedure from fairly crude and hence cheap equipment. However, both the reading of the extra rows (ideally, 8 rows would be enough to record the accurate coordinates) and the special computation should add less than a second to the time taken for each event. The computer would first compute X and Y from the recorded "elbow" angles, and then the coordinates of the midpoint of slit B (or C) after it has travelled the distance b (or c) in the direction α. Knowing the coordinates of all the raster dots, it will identify the one nearest to the computed point and will use its accurate coordinates to correct X and Y by moving the point (X, Y) in the direction α; from that it will then compute the coordinates of the midpoint of slit A on crossing the track. Those coordinates will correspond to a point that lies accurately on the track, but whose position along is uncertain by about $\frac{1}{2}$ mm ; usually that won't matter.

To measure a point (e.g. an endpoint) that cannot be identified by the photocell behind A one will set that point as accurately as possible on the mark M and then press a button that causes the fixed distance AM to be punched as the value of a. To eliminate the uncertainty across α one turns the box by about 90° and repeats. Fiducial marks in the shape of a cross can be measured accurately by letting α scan over two arms of the cross. The computer programme can see to it that two successive measurements, close together and with the α's about orthogonal, get combined to give a point that is accurate in both directions.

4. History and acknowledgment

The first proposal for RHODA was made in July 1961, rather in a hurry. A "wash board" was to be used instead of optical bench marks; that would have been hard to make and would no doubt have corrugated the soul of the operator. "Polka dots" were suggested in April 1962, thrown onto the table by a separate projector. Alan Oxley then suggested that a coloured raster should be embodied in the film guide and the film clamped against it, eliminating differential distortion and unsteadiness. At first I thought of a box with no mechanical constraints, containing a transmitter to send out its information, running on dry batteries, and with its position roughly digitized by servo-operated light beams. That could be done and would be very pleasant to use but is more expensive and has been dropped for the time being.

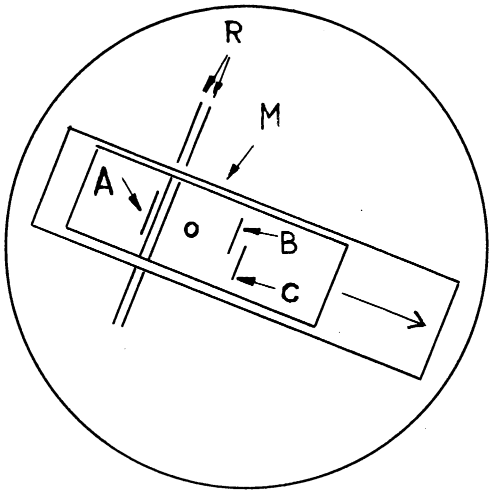

Figure 1

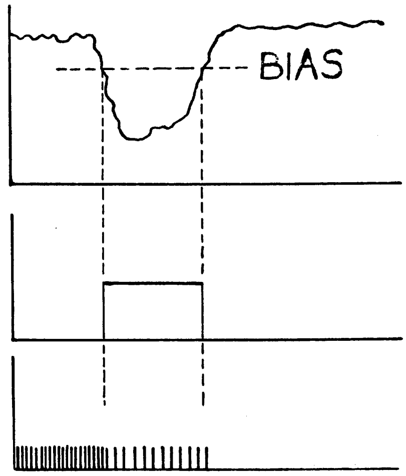

Figure 2

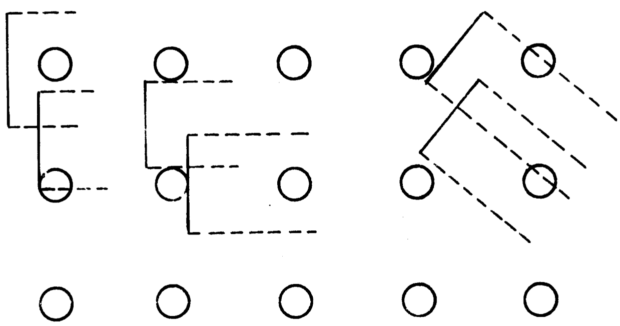

Figure 3